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Bα AND Ne II LINE SPECTROSCOPY IN THE VICINITY OF THE GALACTIC CENTER SOURCE IRS 16

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ABSTRACT

Bα (4.05 μm) and [Ne II] (12.81 μm) line spectra at spatial resolutions of $\sim$ 3" and spectral resolutions of 80 km s^{-1} have been obtained on a grid of positions surrounding IRS 16, which may be at the Galactic center. The Bα and [Ne II] line profiles agree within the uncertainties and neither set of spectra shows evidence of ionized gas associated with IRS 16 over a velocity range of -500 to +450 km s^{-1}. A spectrum of Bα from an 8" beam centered on IRS 16 and covering -7500 to +6500 km s^{-1} with 500 km s^{-1} resolution shows marginal evidence for a broad-line component. These data imply that no concentration of moderate velocity gas ($|v| < 300$ km s^{-1}) is directly associated with IRS 16 and that the ionized gas near IRS 16 is for the most part neither very dense nor of very high velocity.

INTRODUCTION

The nature of the peculiar object IRS 16, which lies at or very near the center of the Galaxy and which may be associated with an ultracompact radio source, is uncertain. IRS 16 has been spatially resolved in the near infrared continuum and lies near the center of the extended near infrared emission, suggesting that it is the central stellar concentration of the Galaxy.[1] However, absorption due to the 2.3 μm CO bands is not seen at the level expected in a star cluster.[2] Bα, Bγ, and [Ne II] emission lines are seen toward IRS 16,[3-7] but no definite relationship of that source with any particular velocity component of the ionized gas has been established. If IRS 16 is the core of a central star cluster, gas collecting there would be expected to emit symmetric lines with widths less than or comparable to that of the surrounding region, $\sim$300 km s^{-1}. Alternatively, if a massive object is present at the center, broader lines would be expected. In addition, if the ionized gas near IRS 16 were very dense, [Ne II] and other fine structure lines might be suppressed.

Previous studies have not had sufficient angular resolution to separate an ionized gas component associated with IRS 16 from nearby clouds and have observed too small a range of velocity to detect a line as broad as those seen, for example, from Seyfert galaxies. In an attempt to improve on them, we have obtained closely spaced grids of Bα and [Ne II] spectra with angular resolutions of ~3" and spectral resolutions of 80 km s^{-1} to search for moderate velocity dispersion gas associated with IRS 16 and we have obtained a lower resolution spectrum covering a wide velocity range to search for a broad-line component of Bα.

OBSERVATIONS

The high resolution Bα spectra, shown in Figure 1, were obtained with a Fabry-Perot and cooled grating spectrometer[8] at the 5m Hale telescope at Palomar Observatory during 1981 July. A 2".5 focal plane aperture and a spectral resolution of 80 km s^{-1} were used. IRS 16 was centered in the beam by first offsetting from IRS 7 and then maximizing the 2μm signal. A Bα spectrum was obtained at this position and at a hexagonal pattern of positions, each one 2" from IRS 16.

The [Ne II] spectra, shown in Figure 2, were obtained during 1979 May at the 2.5m du Pont telescope of Las Campanas Observatory, using a cooled Fabry-Perot and grating spectrometer.[9] A spectral resolution corresponding to 80 km s^{-1} and a 3" aperture were used. Spectra were taken on a rectangular grid, with positions spaced by $0^s.15$ in RA and 2" in Dec. The positions were measured by offsetting from a visual field star at $17^h42^m30^s.0$, -28°59'01" (1950). IRS 16 lies approximately half way between the positions of spectra 6 and 7.

The low resolution Bα spectrum, in Figure 3, was measured in 1981 April at the du Pont telescope with a stepping grating spectrometer.[8] The spectrum was taken through an 8" aperture centered on the 2μm continuum peak of IRS 16, and covered -7500 to +6500 km s^{-1} with 500 km s^{-1} resolution.

Cumulative positional uncertainties due to offsetting and guiding were ~1" for all observations and the seeing disks were in all cases smaller than the apertures used. Absolute flux calibrations should be accurate to $\pm$20 percent; and within each grid relative fluxes are accurate to $\pm$5 percent.

Bα AND [Ne II] HIGH RESOLUTION SPECTRA

The Bα and [Ne II] spectra in Figures 1 and 2 show emission over at least -300 to +250 km s^{-1} as well as rapid variations in the line intensities and profiles. The lines increase in width to the southwest and increase in strength to the south and east of IRS 16. These variations are apparently due to the presence of several clouds in the vicinity of IRS 16.[6] It appears, however, that no cloud is centered on IRS 16 itself; there is no obvious component of the line toward IRS 16 in this velocity range which cannot be attributed to nearby clouds. To quantify this conclusion we have compared the average of the six Bα spectra surrounding IRS 16 with the central spectrum. The uppermost panel in Figure 1 shows the difference between IRS 16 and the average of its surroundings, plotted on the same scale as the original spectra. It is clear that no velocity component peaks on IRS 16. The total intensities (line plus continuum) integrated over the velocity range -500 to +450 km s^{-1}, of the spectrum of IRS 16 and that of the surrounding region agree to better than 4 percent. Since the ionized gas clouds in the Galactic center are extended, with sizes of typically 4", it seems probable that the emission seen toward IRS 16 is due to nearby clouds which overlap the line of sight to IRS 16.

A similar comparison of the [Ne II] line profile with that of the surrounding region was also made. Again no component of the line clearly associated with IRS 16 was seen. There is some evidence in the [Ne II] spectra, which cover a wider area than those of Bα, that features shift toward the blue in going to the west or southwest. It is difficult to say whether this is due to rotation of extended clouds of gas or simply overlapping red- and blue-shifted clouds. In any case it is not possible to choose a center of rotation unambiguously. As in the Bα spectra, the emission toward IRS 16 appears to be a continuation of the pattern seen near it, and does not show a separate gas concentration.

Uncertainty in the relative positioning of the Bα and [Ne II] spectra make a detailed comparison of the two lines difficult. In general, however, they agree quite well. For example, note the double-peaked lines to the southwest of IRS 16 and the overall increase in intensity toward the southeast. The intensity gradient also agrees well with the structure of the region at 10 μm. This indicates that in the velocity range -500 to + 450 km s^{-1} there is no dense ($n_e > 3 \times 10^5$ cm^{-3}) ionized gas which would produce the Bα emission but not the forbidden [Ne II] line.

Bα LOW RESOLUTION SPECTRUM

The 500 km s^{-1} resolution Bα spectrum (Figure 3) was fitted with a Gaussian line profile plus a linear continuum. The line fit, which has a FWHM of 600 km s^{-1}, is consistent with the Bα line width found from the higher resolution observations reported above. There is evidence for a slight excess of emission centered at $\sim$4000 km s^{-1} on either side of the narrow line, but this may be due to instrumental effects. However, a spectrum of the bright compact HII region G333.6-0.2 has a flat continuum when the same data reduction technique is applied. It can be concluded nonetheless that any broad-line component near IRS 16 has less than a few percent of the flux density of the narrow component and that the flux of a broad component, integrated over -7500 to +6500 km s^{-1}, is significantly less than that of the narrow line in an 8" beam.

THE 4 μm CONTINUUM

Five of the Bα spectra in Figure 1 show a strong continuum at 4 μm. The flux density of the continuum agrees with that of Becklin et al[10], to within the uncertainties imposed by the differences in aperture size (3".8 versus 2".5), pointing, and photometric bandwidths used. We note that the equivalent width of

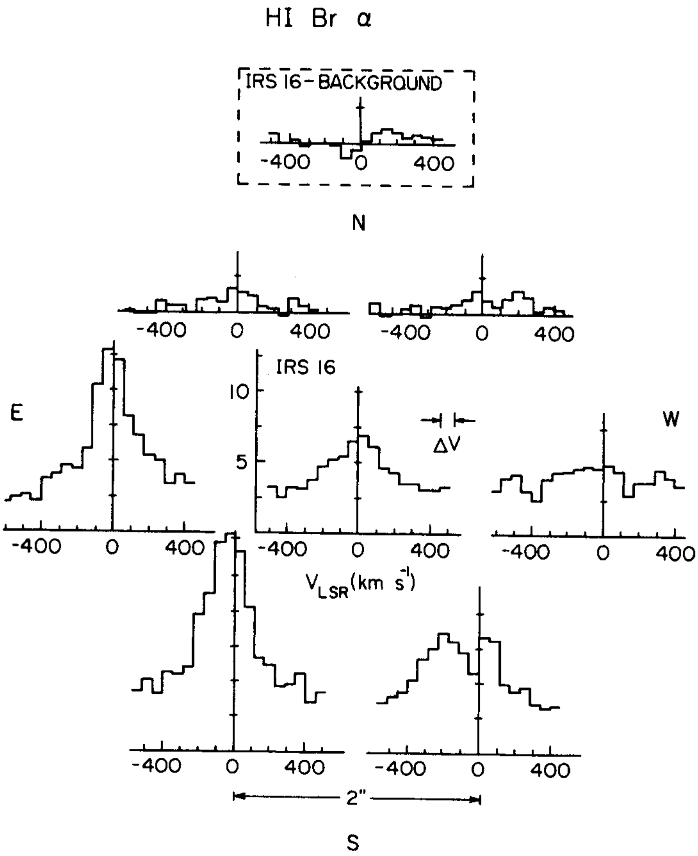

Fig. 1. Spectra of Bα (4.05 μm) near IRS 16. The data are binned in 57.5 km s^{-1} intervals, and the velocity resolution is 80 km s^{-1}. The flux scales are labeled in units of 10^{-20} W/cm^2 cm^{-1} in the 2".5 diameter beam. The central spectrum was taken at the position of IRS 16; the spectrum enclosed by dashed lines is the difference of the central spectrum and the average of the six surrounding spectra.

Bα changes by at least a factor of 10 in the east-west direction across IRS 16, while much less change is seen in the [Ne II] spectra of Figure 2. Such a change could be due to rapid changes in the dust temperature or ionization, but is most easily interpreted as arising from additional sources of non-dust (e.g. stellar) sources of continuum radiation. It seems likely then that the excess 4 μm continuum which is seen in the central, W, and SW grid spectra is due to IRS 16 itself. More detailed mapping measurements would be necessary to resolve IRS 16 out of the 4 μm background.

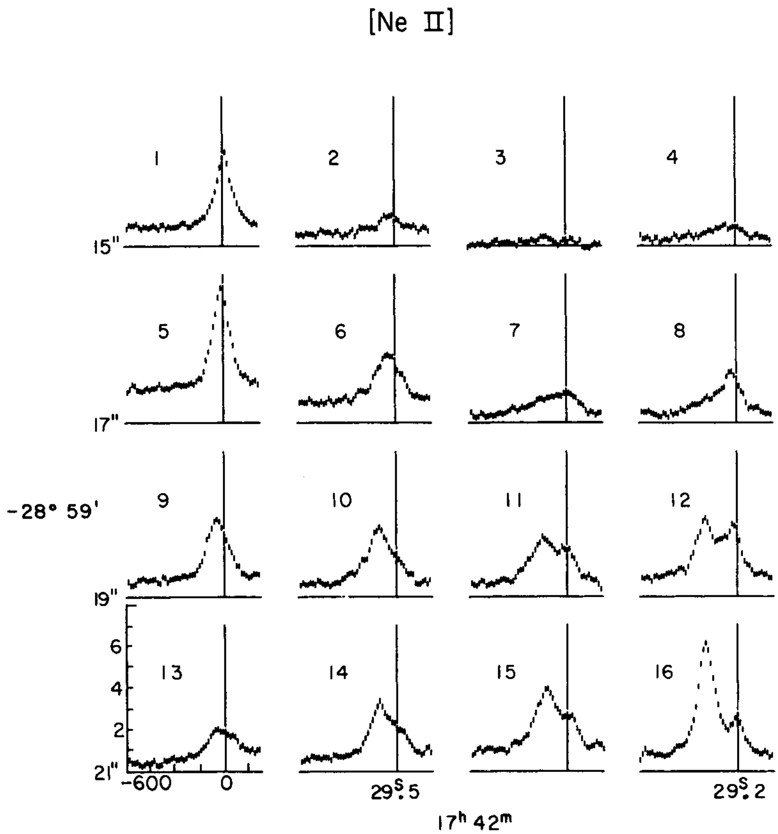

Fig. 2. Spectra of [Ne II] (12.81 μm) near IRS 16. The data are binned in 20 km s^{-1} intervals, and the velocity resolution is 80 km s^{-1}. The intensity scale is labeled in units of 10^{-8} W/cm^2 cm^{-1} sr. IRS 16 lies approximately half way between spectra 6 and 7.

SUMMARY

1. No feature which is centered spatially on IRS 16 is seen in either Bα or [Ne II] between -500 and +450 km s^{-1}.
2. Over the region mapped, no feature is seen in Bα which is not also seen in the [Ne II] forbidden line.
3. A broad-line component of Bα in the range -7500 to +6500 km s^{-1} is at best only a minor part of the line emission seen toward IRS 16.

These conclusions indicate that whatever the nature of IRS 16 is relatively little or no ionized gas, whether of high or low density and high or low velocity dispersion, is associated with its vicinity.

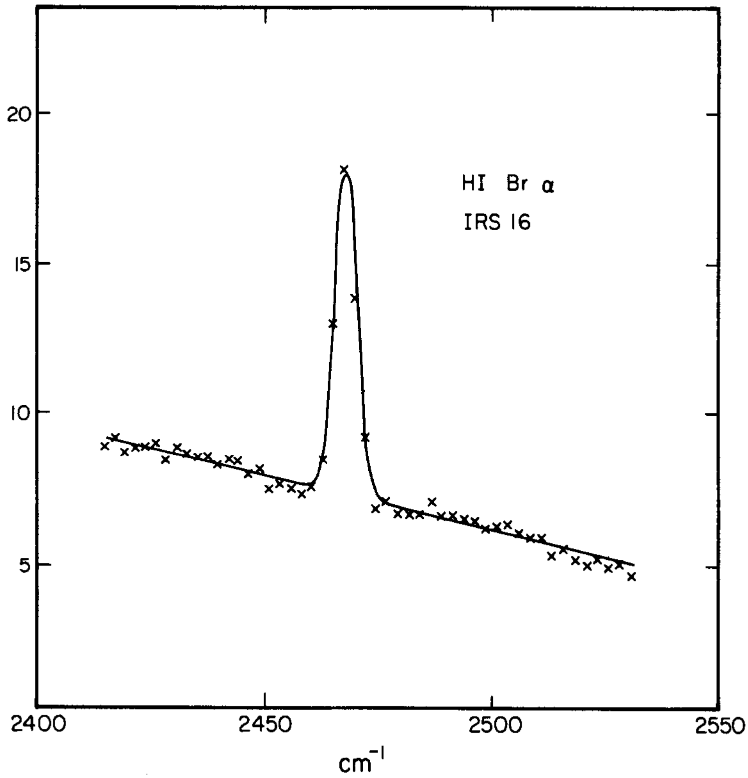

Fig. 3. Spectrum of Bα from an 8" beam centered on IRS 16. Data points are separated by 286 km s^{-1}, and the velocity resolution is 500 km s^{-1}. The flux scale is labeled in units of 10^{-20} W/cm^2 cm^{-1}. Flux calibration and removal of telluric and instrumental features were obtained from a comparison star. The smooth curve is the best fit Gaussian line plus linear continuum.

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